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A global approach to the gender gap in mathematical, computing and natural sciences: How to measure it, how to reduce it?

The participation of women in many fields of science remains a subject of concern worldwide. In this Commentary, we describe one of three collaborative projects – the Gender Gap project – funded by the International Science Council (ISC) and the 11 partners of the project. This project is the only one of the three that addresses an issue of such relevance for society. The objectives of the project are to provide evidence on which interventions can be based, and to make available material on best practice that has been proven by test. The project includes a joint global survey and a bibliometric analysis, both of which have an emphasis on comparing and contrasting results from less developed countries and from more developed countries.

Background

Mathematical and natural sciences have long traditions of women who have made significant contributions. However, participation by women remains small across the globe. While there are excellent studies, our data remain largely local, and much of the existing data are now out of date in the light of recent socio-political changes.

Two major surveys provide the foundation for this work. In physics, the International Union of Pure and Applied Physics (IUPAP) conducted a Global Survey of Physicists in 2009/2010.[1,2] The survey was conducted in eight languages, with 14 932 respondents in 130 countries. The results were first announced at the 4th IUPAP International Conference of Women in Physics[3], and have proved useful in guiding the choice of interventions appropriate in physics. In mathematics, a web-based bibliometric survey of publication patterns among men and women was carried out, using comprehensive metadata sources.[4] Among the findings was that over the years 1970 to 2010, the fraction of publications by women in top journals was of the order of 10% of total authorship.

The Gender Gap project

Since these surveys, much has changed. In geopolitical terms, the Arab Spring has affected academic environments, and anecdotal evidence indicates that the effects on women have been significant. The number of women in science is no longer rising in the European Union; and the number of bachelor's degrees in physics earned by women in the USA has fallen significantly since 2015.[5] Science funding has fallen in a significant number of countries, and science itself is subject to 'post-expert' public opinion. The education of girls is under serious threat in certain countries. However, there are many successful new initiatives in place, and many projects are addressing better science education and gender in science.

Therefore, a proposal was made to ISC to engage in a joint project with the following objectives. Firstly, as up-to-date evidence is needed, a global survey and a study of publication patterns are currently being conducted. Secondly, this joint project provides an excellent opportunity for collaborating with social scientists working in the fields of gender and science, noting that ISC was formed by the merger of the International Council of Science (ICSU) and the International Social Sciences Council (ISSC) in 2018. Thirdly, easy access to materials that have proved successful in encouraging women and girls in science will be provided, and fourthly, based on the evidence, successful practical policies and actions for reducing the gender gap will be recommended.

The project[6] is led by the International Mathematical Union, with the International Union of Pure and Applied Chemistry and IUPAP as executive partners. The other project partners are: IAU (Astronomy), ICIAM (Industrial and Applied Mathematics), IUBS (Biological Sciences), UNESCO (United Nations Educational, Scientific and Cultural Organization), IUHPST (History and Philosophy of Science and Technology), ACM (Computer Science), GenderInSite (Gender in Science, Innovation, Technology and Engineering) and OWSD (Organisation of Women for Science for the Developing World).

Global Survey of Mathematical, Computing and Natural Scientists

The survey has been developed and implemented through the American Institute of Physics Statistical Research Center as part of the collaboration of social scientists and natural scientists. It is probable that the results of the global survey will provide comparisons between disciplines, answering some persistent questions about why one discipline is generally more attractive than another to women. Contrasts and similarities will be sought between regions; countries that are very highly developed and less developed; employment in academia, industry and schools; and younger and older respondents. The survey addresses a series of experiences through sections that cover the development of interest in science, education and career experiences, family support for career choices, access to resources needed to conduct science, and opportunities to contribute to the scientific enterprise, for both women and men. It is designed to provide longitudinal data through compatibility with the Global Survey of Physicists of 2011.

This survey is based on a snowball sample, and is not designed to provide data on numbers or proportions of women among scientists. In this regard, it is complementary to the SAGA surveys[7] carried out through UNESCO, and use of both sets of results, where available, promises insightful conclusions.

The survey was translated, with the aid of scientists working with professional translators, into seven languages: English, French, Chinese, Japanese, Russian, Spanish and Arabic. The choice of languages was based both on those in use at the United Nations and on those used for the Global Survey of Physicists.

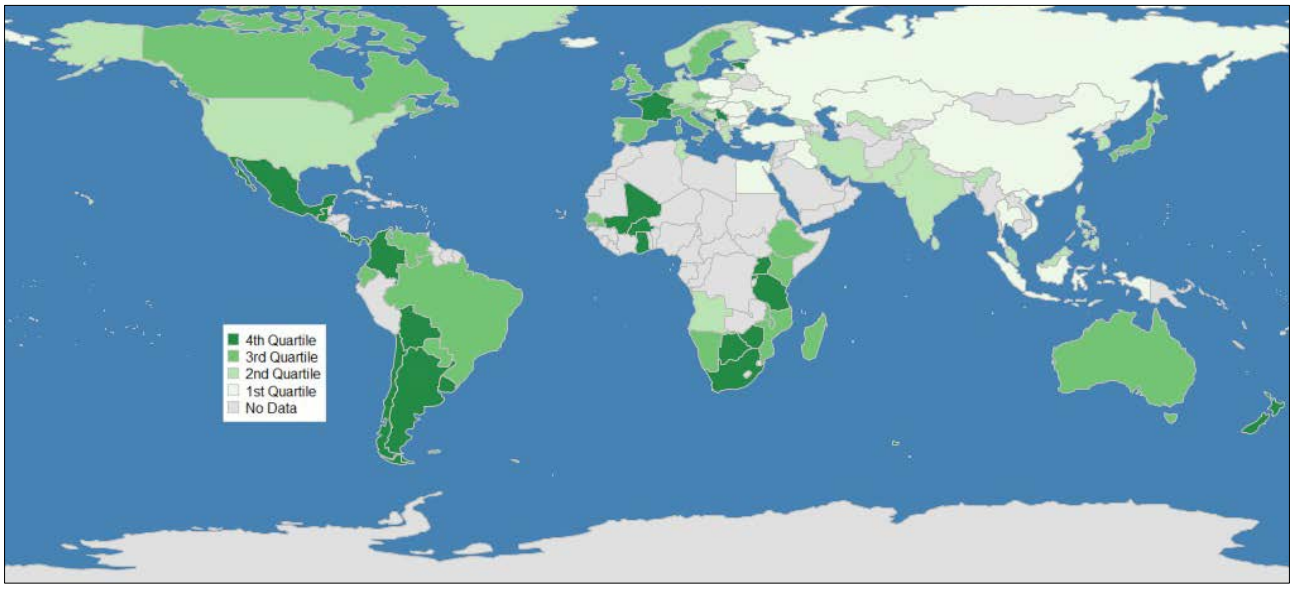

Figure 1: Proportion of responding scientists by country (1 November 2018).

Because multiple cultures are surveyed, three regional workshops were held: in Taiwan (National Taiwan Normal University, 7–8 November 2017), Colombia (Universidad de los Andes, 22–24 November 2017) and South Africa (African Institute of Mathematical Sciences, South Africa, 1–2 December 2017). The workshops' objectives were to inform diverse regional science communities about the project, present its three tasks, make contacts with people who are instrumental for the success of the project, and get input from Asia, Latin America and Africa to ensure the project reflects local realities. Additionally, these workshops were aimed at organising the dissemination of information about the project in Asia, Africa and Latin-America and to encourage the active participation of individuals and organisations of these regions. These surveys used special input from the three major regions of the ISC Regional Offices – Africa; Asia and the Pacific; and Latin America and the Caribbean – and were generously welcomed through these organisations. In each workshop, 30–40 participants could be invited. A principle of this project is that it includes men, both in the surveys and in the organisation and implementation of the project. The countries represented were chosen for the optimal representation of regions and cultures. In South Africa these were: Algeria, Burkina Faso, Botswana, Cameroon, Ethiopia, France, Kenya, Lesotho, Morocco, Madagascar, Malawi, Nigeria, South Africa, Swaziland, Uganda, USA and Zimbabwe; in Taiwan: Australia, China, France, India, Israel, Japan, Korea, Nepal, Malaysia, Taiwan, Thailand and USA; and in Colombia: Argentina, Brazil, Chile, Colombia, Costa Rica, Cuba, El Salvador, Mexico, Perú and USA.

Through consensus, debate and written responses, participants at each workshop worked hard to provide critical feedback for the survey creation team. Once completed, results from each of the workshops were organised and compared to determine the final survey instrument. In all cases, contributions from all attendees and insights from different disciplines and countries were shared, further helping refine the global survey to be culturally appropriate both in terms of language as well as in substance.

The Latin American workshop took place immediately after a workshop on professional skills for young people in science and engineering, with an exchange session to learn about the special needs of young people.[8] During the Asian workshop, participants emphasised the need to ensure that the questionnaire was applicable to individual respondents in industry. As a result, questions and response items were added that include patents and other measures of success in industry. Consequently, the language of the survey is relevant to industry-based participants, as well as academics and other professionals. During the African workshop, participants worked to ensure that the questions on career disruptions included the realities that scientists throughout Africa face. As a result, responses were expanded to include health, conflict, natural disasters, and other continent-specific answers, and Arabic was added as a language.

The survey was released in May 2018 and can be accessed at https://gender-gap-in-science.org. The number of responses relative to the estimated number of scientists in each country is illustrated in Figure 1.

Analysis will take place at the American Institute of Physics Statistical Research Center in 2019. Preservation of personal confidentiality is a fundamental tenet, and the guiding principle is that analysis cannot be carried out down to samples with fewer than 30 respondents, or with fewer than 5 respondents in a cell.

Joint data-backed study on publishing patterns

The second task is a bibliometric study extended across disciplines, with an ongoing sustainable methodology designed to allow longitudinal studies and updates into the future.

A solid publication record is a key factor in a successful academic career. In mathematics, a recent study by data scientists Mihaljević-Brandt et al.[4] on publication patterns based on comprehensive metadata sources showed a systemic gender imbalance in the publication distribution of mathematicians. Using four decades of data, it was shown that the number of women mathematicians who are publishing has tripled since 1970, but that women publish less than men at the beginning of their careers, and leave academia at a higher rate. High-ranked journals publish fewer articles by women. Some show less than 5% authorships by women, with no change over time. Women published fewer single-authored papers, although their co-author networks are similar in size to those of men.

Ideally, for the purposes of this study, a volunteered identification of gender would be used. However, this is rarely available in the scientific literature. The methodology in automated studies relies on gender inference methods. The data science challenge is to estimate gender (in the present case confined to female, male or unknown) based only on an author's name string, which, in the case of academic papers, is one of the few gender indicators in the public domain. Gender inference application programming interfaces (APIs) are widely used by web services and rely on a collection of records from, for example, baby name lists, censuses and social media profiles. The tool returns the estimated gender with a weighted certainty of assignment. In the study quoted above, gender assignments were made with acceptable confidence for 61% of the authors identified. The scope of this research includes providing sufficient evaluation of the method used. In the first year of the project, the authors benchmarked and compared the gender

inference services available to the project, making this one of the few well-validated studies. In order to define benchmarks, error metrics and constraints have had to be devised.

This survey covers multiple languages, alphabets and cultures. An estimate of the origin of the name can be made, and confidence limits given, for African, Asian and European names, and names derived from these, using additional APIs, which are also undergoing evaluation for the present purpose.

The study of publishing practices in mathematics is now undergoing extension to astronomy, and will then be applied to physics, chemistry, biology and computer science. It is intended that the resulting engines could be automated and used in longitudinal studies in the future.

Database of good practices

The third task is to use the accumulated evidence to advise on initiatives which have a successful track record, taking regional and cultural differences into account. There are many initiatives across the world, but relatively few have undergone evaluation.

The task of finding published evaluated interventions aimed at increasing the participation of girls and women in science will lead to a database, which will be hosted by the International Mathematical Union and made available through the partners. It is a goal to add searches that make the material accessible. Databases have a limited life, although much effort is invested in them; therefore, guidance for the identification and evaluation of initiatives, and additions to the database, must be included.

This work is aimed both at young women, and at those who provide guidance to girls and young women, including parents and teachers – an important point in developing countries. Experience indicates that good information is needed, particularly by the family, about the stability of careers in science and the availability of jobs. The challenge of reaching parents is a significant one, and for that reason is rarely undertaken.

Conclusions

Knowledge of science and technology is universal, but it is shaped by local culture.[9] The Gender Gap project aims to provide a global set of data on experiences of both women and men in science, with comparisons across regions and for less developed and very highly developed countries.

The Gender Gap project was initiated in 2016 and will conclude in 2019. It is intended that the database of good practices and results of the survey and the publication study will be carried forward by all partners and ISC in formulating coherent, sound, evidence-based initiatives, in which good intentions are guided by solid data, and in which regional and cultural relevance can be found.

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